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Sustainable hydrogen evaluation in logistics; SHEL

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Abstract

Materials handling vehicles are currently powered by either electric motor based on lead-acid batteries or combustion engines employing diesel or liquefied petroleum gas. Fuel cells offer significant advantage over the competing technology.

SHEL is a three-year European project involving 13 partners from six countries. The overall aim of the project is to deploy 10 fuel-cell powered forklift trucks and associated hydrogen refuelling infrastructure across 3 sites in Europe. Real time information will be gathered, and efficient procedures will be developed to reduce the time required for product certification and infrastructural build approval.

Key words: Forklift truck (FLT); proton exchange membrane fuel cell (PEM FC), SHEL

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1. Introduction

Materials handling vehicles are currently used to facilitate and transport the movement of goods at, for example, distribution centres, airports and ports. They are currently powered by either electric motors based on lead-acid battery technology or combustion engines employing diesel or liquefied petroleum gas; with the former category mainly used indoors and the latter utilised primarily for outdoor applications. The main disadvantage with battery powered vehicles is the requirement for periodical re-charging of the battery. Charging a normal material handling vehicle battery takes approximately between 8-10 hours and in some cases batteries also have to be left to cool down for an additional number of hours before usage (depending on the battery technology used). Moreover, unless sophisticated AC power systems are employed involving inverters, the performance of the truck slowly tails off as the battery discharges, so that the truck is difficult to use effectively towards the end of a shift.

Development of H2&FC powered forklifts began in the late 1990s, with Linde launching the first prototype fuel cell forklift in 1997. Since then the number of companies investing in this H2&FC application area has grown. The development focus in recent years has been on fleet trials of fuel cell forklifts at user warehouses and distribution centres [1]. Data from these fleet trials is being used by the forklift manufacturers and system integrators to improve the design of the fuel cell products. The trials are also helping to grow demand for fuel cell forklifts, with several of the forklift users.

Previous studies have identified that utilising fuel-cells in materials handling vehicles, particularly forklifts, can lead to increased productivity compared to existing battery powered vehicles, especially in multi-shift, high throughput settings [2] [3]. The main advantages include less downtime and constant power output and performance. A fuel cell powered truck will continue to operate at optimum power output until the fuel is depleted, rather than undergo the drop in performance seen in battery powered vehicles when the batteries are in a significantly discharged condition.

Many early successes for fuel cells have been in the area of battery replacement, both for portable systems as well as for material handling vehicles such as lift trucks [4]. Given the high customer expectations about system reliability, durability, and performance, use of fuel cells in lift trucks is challenging but offers more potential for expansion into other mass market areas. Success of a significant number of demonstration projects, in particular in the US, has led to the adoption of the technology by large distribution centres by companies such as Wallmart and FedEx [5].

Most of the prototypes to date have used PEM fuel cells, in conjunction with batteries or super capacitors to make “plug-n-play” fuel cell hybrid systems that can replace the existing battery power pack on battery forklifts. However, at least one industry consortium (see Table 1) is researching the potential of DMFC technology for this sector and in May 2008 Linde launched a prototype hydrogen ICE forklift.

The research and development of hydrogen and fuel cell powered material handling vehicles involves organisations from across the spectrum; manufacturers of fuel cell stacks, system integrators who are involved in building the fuel cell technology into hybrid power pack units that can be fitted to forklifts, pallet trucks and other similar vehicles, and material handling vehicle original equipment manufacturers (OEMs), whilst users of material handling vehicles enable testing of the fuel cell vehicles in the field. An array of key organisations active in the research, development and testing of hydrogen and fuel cell powered material handling vehicles are given in Table 1 and Table 2.

Table1: Key Players; Stack/system producer and system integrators

FC Stack Producers & Research Institutes	*FC System produced*	System Integrators
Ballard (Canada)	*FC Velocity-955L*	
Hydrogenics (Canada)	*HyPx*	Hydrogenics (Canada)
H2 Logic (Denmark)	*H2 Drive*	H2 Logic (Denmark)
Plug Power (US)	*Gen Drive*	Plug Power (US)
Julich Forschungzentrum (Germany)	*DMFC power pack for pallet trucks*	Julich Forschungzentrum (Germany)
Nedstack (Holland)		
Nuvera Fuel Cells (US)		
Proton Motor (Germany)		
		Hoppecke (Germany)
		Fronius International (Austria)

Table 2: Key players; Hydrogen producers and forklift OEMs

Hydrogen Producers	Forklift OEMs
Air gas Inc. (US)	Crown (US)
Air Liquide (France)	Cumitas (Turkey)
Air Product (US/EU)	DanTruck (Denmark)
Linde Group (Germany)	Jungheinrcih (Germany)
Praxair (US)	KION Group
	Lift One
	Linde (Germany)
	Raymond (US)
	STILL (Germany)

2. European material handling projects

The primary barriers to widespread use of hydrogen fuel cells for material handling equipment are concerns about the safety of hydrogen storage and fuelling equipment, operating costs for fuel and maintenance, and the long-term reliability of fuel cells. The purpose of demonstration projects is to confirm that hydrogen fuel cells are a safe and economical alternative to batteries for powering electric lift trucks.

Although there have been a number of demonstration projects in Europe during the past decade, these have been small scale, mostly involving very few FLTs. More recently, the Fuel Cell and Hydrogen Joint Undertaking (FCH JU) has been established with an objective to promote, support and accelerate the research and deployment process of fuel cell and hydrogen technology in Europe. FCH JU with a total budget of 940 million Euros for the period 2008 to 2013, provided by the European Commission and the private sector, provides funding for targeted R&D programmes.

Two 3-year European FLT demonstration Projects commenced in 2011; Sustainable Hydrogen Evaluation in Logistics (SHEL) and HyLift demo; both projects are part-funded by the European Joint Undertaking for Fuel Cells and Hydrogen (FCH JU). The two latter projects aim to deploy 10 and 30 FLTs respectively, in representative sites across Europe, within the EU framework of system cost and lifetime targets. H2 refuelling infrastructure cost to be included within the overall financial analysis. Furthermore, the projects aim to address the requirement for a common approach at EU level to address the certification process for overall site, infrastructure, and material handling vehicle certification.

3. Sustainable hydrogen evaluation in logistics; SHEL

Sustainable Hydrogen Evaluation in Logistics (SHEL) is a consortium of 13 European partners from 6 countries aiming to demonstrate the market readiness for hydrogen fuel-cell materials-handling vehicles and the associated refuelling infrastructure. The consortium is made up of a strong selection of partners from industry and public sector research organisations that bring a range of complementary skills, experiences and networks to achieve the project objectives. Figure 1 depicts the partners contributing to SHEL consortium.

Figure 1: SHEL partners

SHEL's objective is to demonstrate 10 units of hydrogen fuel cell-powered FLTs and the associated hydrogen refuelling infrastructure in the UK, Spain and Turkey within three market segments (Air/Seaport, Light Logistics and Industrial), obtaining real time data during the utilisation phase. Each deployment site is representative of one of the market segments deemed likely for early commercialisation. Project also aims to develop a continuation plan for a further 10 sites and an estimated 200 vehicles to create market pull in the 3 market segments. Greece was envisaged to be a part of SHEL's continuation plan.

SHEL project has been organised in 7 Work Packages (WPs), with contribution from differ project partners. Table 3 provides a summary of the WPs and their corresponding scope within the overall project plan.

Table 3: SHEL work packages

Work Package	Scope	Notes
1	Project Management	
2	Bench Marking	Cost information & stakeholders identification
3	Hydrogen Infrastructure	Design concept for modular refuelling station
4	Certification & Planning	Standards & certification process Safe operation of FLTs during the demonstration
5	FLT preparation	FC integration & testing of the FLTs Development & implementation of on-board monitoring
6	Demonstration	18 months in 3 sites
7	Continuation Plan & Dissemination	Plan for 10 further sites Two sites to start before the end of the project

The SHEL project was set up to evaluate the use of hydrogen fuel cells in logistics starting from a pilot project using Fork Lift Trucks (FLTs). UNIDO-ICHET, one of SHEL partners in Turkey, has already demonstrated the technology by replacing batteries in a Class 1 forklift built with an 8 kW fuel cell, with a storage capacity of 1.6 kg hydrogen and carrying capacity of up to 1.5 tons, refilled from high pressure cylinders with commercial refuelling nozzles. CUMITAS, a major forklift truck manufacturer in Turkey, in association with UNIDO-ICHET will integrate 12kW-Hydrogenics PEMFCs into FLTs for SHEL.

SHEL demonstration phase, scheduled for between 6 and 12 months at each site, are due to commence in 2012. Real time data will be gathered with the intention of demonstrating the advantages inherent with the use of hydrogen fuel cells powered FLTs in comparison to incumbent technologies such as diesel, LPG, and batteries currently in widespread use. Table 4 indicates the intended demonstration sites for the SHEL project.

Table 4: SHEL demonstration sites

Country	Demo Site	H2 Source	Refuelling Method
Turkey	Petkim Petrokyma Chemical Complex	on-site Compressed Storage	Existing Prototype Modular Hydrogen Refuelling Station
Spain	CEGA Logistics	On-site Electrolyser Powered from the Grid	Existing Prototype Modular Hydrogen Refuelling Station
UK	Port of Felixstowe	Tube Trailer	Commercial Hydrogen Refuelling Station

Demonstration will involve forklift trucks with a lifting capacity of 2.5 Tonnes, produced by Cumitas, a major manufacturer of materials handling equipment in Turkey. The integration of 12 kW Hydrogenics fuel cells will be undertaken by UNIDO-ICHET in Turkey.

In Turkey, demonstration is scheduled to take place in Petkim, a major producer of petrochemical product, in Aliağa, Western Turkey. The demo phase involves four forklift trucks, and is planned for one year due to commence in 2012. Hydrogen is produced on-site from chlorine alkali plant (99.99800% H2, 304 kg/h, Pressure 28.2 kg/Cm^{2}g), and refueling will utilize a commercial filling station.

In Spain, the demonstration site is at CEGA Logistics warehousing facility in Artapadura, North Eastern Spain. Two reach forklifts will be deployed, for two shifts/day 5 days/week, for a period of one year. Hydrogen will be produced on-site alkaline electrolyser (5Nm3/min @20 bar) and fuelling via a commercial fuelling station.

In the UK, the planned demo site is the Port of Felixstowe, South East England. Four forklift trucks will be deployed for a period of six months. Hydrogen will be delivered by tube trailers, and an Air Products Series 100 hydrogen fuelling station is used for refilling, dispensing hydrogen at 350 bar.

4. Progress to date

To pave the way for wider acceptance of the technology, SHEL has developed a comprehensive database of European stakeholders including local and provincial governments, logistics service providers, European associations, European and international hydrogen organisations, knowledge institutes, trade bodies, original equipment manufacturers (OEMs).

An on-board vehicle monitoring system has been developed to aid the gathering of real time information. Based on the data collected during the demo phase, detailed well-to-wheel analysis will be undertaken to ascertain the CO2 savings potential of such vehicles in 3 different likely early market applications (Seaports, Light Logistics and Industrial).

Qualitative risk analysis will be undertaken for each site prior to the commencement of the demo phase. Certification process for each demo site will culminate in a comprehensive report for each site in the context of the national and European legal framework.

Work is underway SHEL aims to identify and develop a European supply chain of companies which can meet current end user technical requirements for commercialisation and competitiveness. Moreover, building upon the work of the previous EU projects, rapid product certification procedures for 4 European countries are being developed, lending support to efforts to set up a single step approval process for all European member states.

5. Conclusion

Materials handling equipment have been identified as a significant early market for the adoption of fuel cell technology. Demonstration projects provide evidence for the reliability of fuel cells in real application context, and pave the way for widespread technology take up. In addition, targeted R&D funding and policy intervention have a significant impact on the take up of new technology.

The EU has accelerated its commitment to the FC technology by setting specific goals for adoption of technology within each market sector. Current EU-funded demonstration projects, including SHEL, together with the EU commitment to support introduction of fuel-cell-powered material-handling equipment, could facilitate widespread implementation and future commercialisation of the technology within Europe, hence contributing to the ambition of reaching a low carbon economy within Europe.

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